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Assignment:

Unique Fire Hazards Associated with Surgery in Space

In all of the studies to date on surgery in space, none have considered the increased risks of a fire event during surgery. Safety begins with understanding or awareness of a hazard. The fire dangers on a terrestrial operating room are significant, and it is hypothesized here that these risks are even higher in space, and thus merit study.

The objective of this proposed research is to mitigate the unique fire hazards associated with space medicine. These unique hazards a combination of 1) ignition hazards due to lower ignition energy requirements in microgravity (lasers, cauterizing devices, etc), 2) accidental ignition upon misalignment of lasers, etc due to improper restraint of patient, surgeon, and tools in microgravity, 3) increased risk of electrical arcing in low pressure atmospheres that may be present on future missions, 4) elevated local or ambient oxygen concentrations in the absence of buoyant flow, and 5) accumulation of toxic and flammable vapors from the patient.

The proposed program is a three-prong approach to mitigate the unique fire hazards in space medicine. The three-pronged approach addresses each of the sides of the classic fire triangle.

1. Ignition Sources: We will conduct normal and low gravity experiments to evaluate the potential for increased ignition susceptibility in microgravity, especially under altered atmospheres (higher oxygen, lower pressure), specifically due to electrical arcs and cauterizing or laser devices. Based on these results, recommend equipment and procedures to mitigate the ignition hazards during medical procedures.
2. Oxidizers: Conduct the ignition testing in current and potential future spacecraft atmospheres with lower pressure and higher concentrations of oxygen.

3. Fuels: Review current materials used in medical equipment and supplies, and select one or two of the current materials for the above ignition testing. For example, a cotton cloth soaked in alcohol and a polyethylene tube.

Research Summary Submitted by Fellow:

Unique Fire Hazards Associated with Surgery in Space

PROJECT DESCRIPTION:

Procedures to address medical emergencies on spacecraft must be planned for, especially as the duration of manned flight missions increases. Terrestrial surgery frequently involves the simultaneous use of flammable materials (drapes, endotracheal tubes, intestinal gases), strong oxidizers (oxygen, nitrous oxide) and high-energy surgical tools (lasers, electrocautery) and there is thus significant fire risk. While rare, operating room fires have been reported, and it is likely that many unreported fires have occurred. Since 1989, Professor Sidebotham has studied several operating room fire safety issues with Gerald Wolf (an anesthesiologist) and their Masters level graduate students. One conclusion of this work is that medical procedures were developed without primary consideration of fire risk. If they had, it is possible that many of the inherent risks associated with surgery could have been avoided. The long-term goal of the present project is to guarantee that the same mistake is not made in the space program.

The initial phase of the project was conducted this summer at the NASA Glenn Research Center in the 2.2 second drop tower. An experimental investigation was conducted to determine the role of gravity on endotracheal tube fires. Previous work in normal gravity has shown that the accidental ignition of polyvinyl chloride (PVC) endotracheal tubes (breathing tubes used during general anesthesia) by high energy surgical devices results in an opposed flow flame spreading process along the inner surface of the tube. This primary flame consumes oxygen fed to it, and produces fuel vapors, which can ignite secondary flames depending on where they exit. The nature and severity of these flames are strongly dependent on the flow rate of oxidizer supplied.

A general purpose rig (PIG4) was modified to allow for videotaping the flame spread process in horizontal and vertical PVC tube samples in normal and microgravity for 100% flow rates up to 500 sccm. A safety permit was granted and approximately 50 tests were performed. Each test was videotaped. Video was then digitized and analyzed to obtain flame spread rates. Ambient pressure was 14.7 psia for most tests. A series of tests at lower pressure (7.35 psia) was also conducted.

RESULTS:

The flame spread rates as a function of oxygen flow rate are shown in Figure 1 for all tests conducted. The vertical lines show cases for which ignition was attempted but not achieved. These represent ignition limits associated with the hot wire ignition used in this study, and not necessarily flammability limits. Above approximately 100 sccm, the flame spread rate is the same in normal and microgravity. For lower flow rates, the flame spread rate is higher in normal gravity than in microgravity. Furthermore, the effects of gravity are greater for the horizontal flames than for vertical flames. Finally, lower pressure lowers the flame spread rate primarily above 100 sccm.

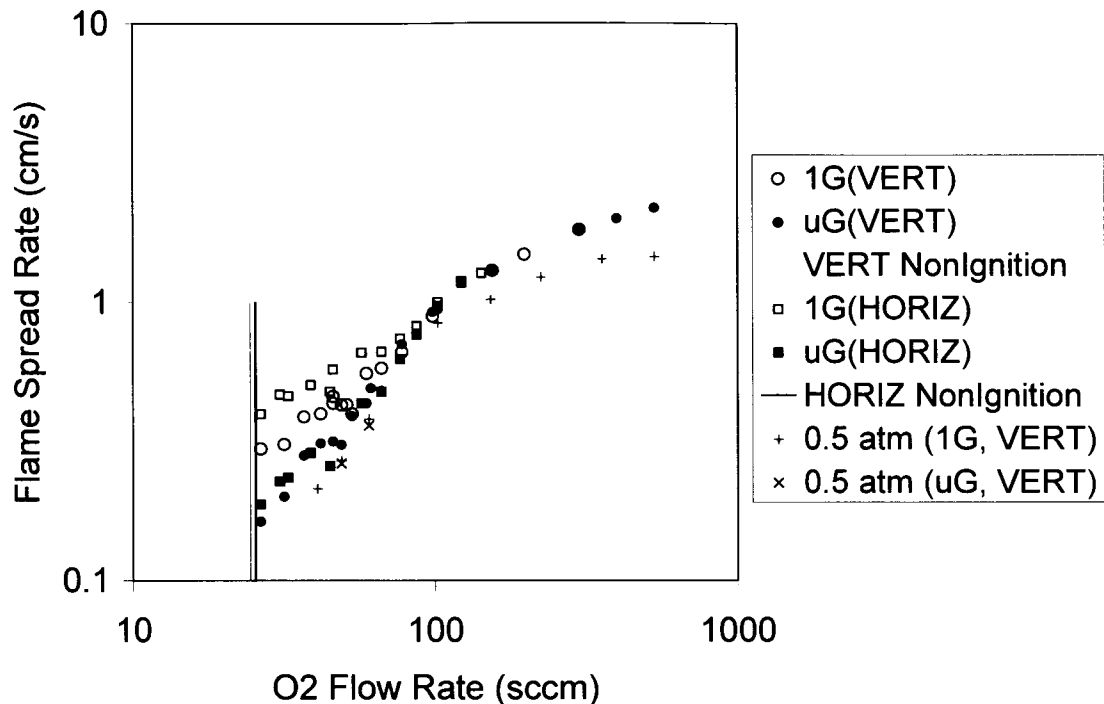


Figure 1

Images of horizontal flames at a relatively low flow (30 sccm) are shown in normal (Fig. 2) and microgravity (Fig. 3). The basic structure of the flames is similar, with the flame running along the bottom of the tube, and a visible vapor trail. There are subtle differences in the shapes of the flames, while the flame speeds vary considerably (0.66 cm/sec and 0.43 cm/sec for the normal and microgravity tests, respectively).

Flames at higher flows show different behavior. For intermediate flow rates (100 – 120 sccm), a second leading edge runs along the top surface (Fig. 4). Above a critical flow rate (approximately 140 sccm) the leading edge completely wets the inner surface in a symmetric flame shapes and the flame speeds are the same in normal and microgravity (Fig. 5), indicating that these flames are controlled by the forced flow of oxygen.

CONCLUSIONS:

- Gravity affects endotracheal tube fires for flow rates below 100 sccm.
- Low gravity environments are safer than normal gravity for this flame type.
- Gravity effects are greater in horizontal tubes than in vertical tubes.
- There is a low flow quenching limit in both normal and low gravity, which may be used to advantage in designing safe procedures for general anesthesia in space.

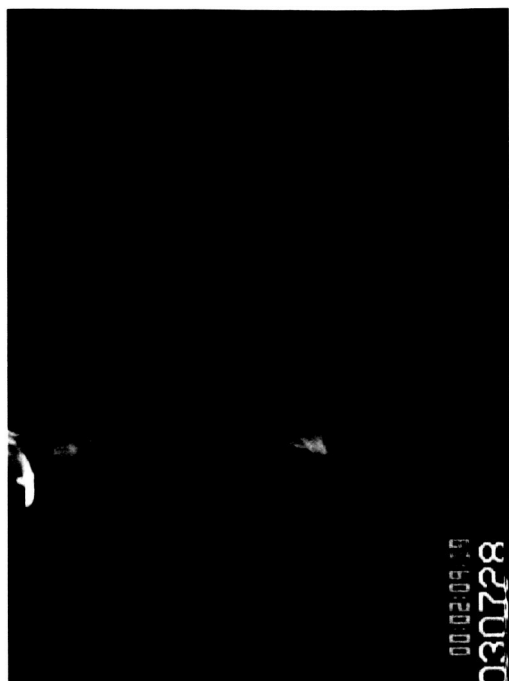


Figure 2: Normal gravity, 30 sccm

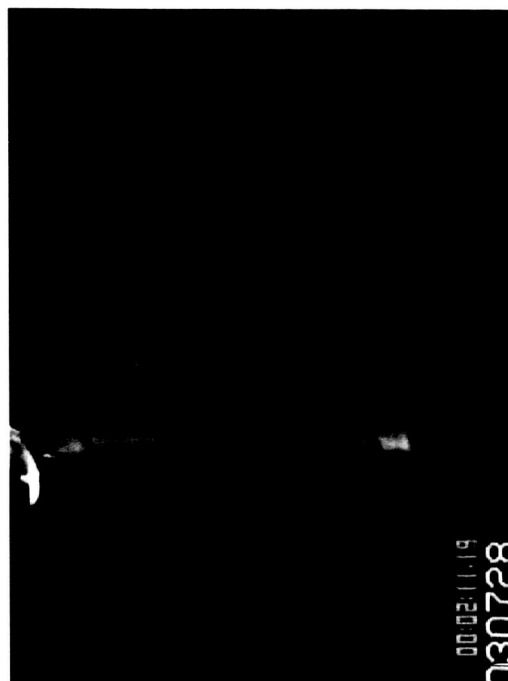


Figure 3: Microgravity, 30 sccm



Figure 4: Microgravity, 120 sccm

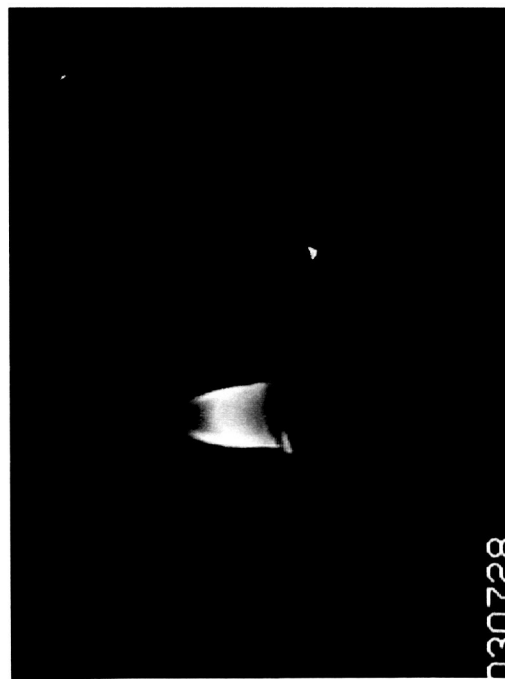


Figure 5: Normal gravity, 140 sccm